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## 7.0 Extreme Values

Extreme values are generally described in terms of probability of occurrence or in terms of return period. For low-probability events, the return period is simply the reciprocal of the probability when the probability is expressed as the likelihood of the event occurring in a given year. As with all estimated extreme values, the uncertainty in the estimates increases as the return period increases. In addition, the extreme value estimates assume that the climate in the future will be the same as it has been since the HMS was established.

### 7.1 Annual Temperature Extremes

Annual maximum and minimum temperatures with return periods from 2 to 1,000 years are listed in Table 7.1. The probabilities of exceeding various maximum and minimum temperatures are shown in Figure 7.1 and Figure 7.2 along with the maximum and minimum temperatures observed at the HMS from 1945 through 2004. The curves were estimated by assuming that the annual extreme temperatures may be fit using a normal distribution and calculating distribution parameters from the observed data.

### 7.2 Precipitation Rates

Maximum precipitation rates for return periods of 2 to 1,000 years are listed in Table 7.2. The corresponding precipitation amounts are listed in Table 7.3. The precipitation rate estimates are based on precipitation measurements made at the HMS from 1947 through 2004. The precipitation rates were estimated for each return period assuming a lognormal distribution and distribution parameters calculated from the data. Figure 7.3 shows the predicted rates for 1, 3, 6, and 12 hours duration along with the observed data.

### 7.3 Snow

Snow extremes for return periods from 2 to 1,000 years are listed in Table 7.4. The estimates are based on data from the HMS for the 1946-1947 through 2003-2004 snow seasons. The values in the tables were estimated assuming a Type 1 (Gumbel) extreme value distribution (Johnson et al. 1995) using maximum-likelihood estimates (Kinnison 1985) of the distribution parameter values calculated from the HMS data. Figures 7.4, 7.5, and 7.6 show the probabilities of seasonal maximum snowfall, maximum single storm snowfall, and maximum snow depth, respectively with the corresponding HMS data.

### 7.4 Peak Wind Gusts

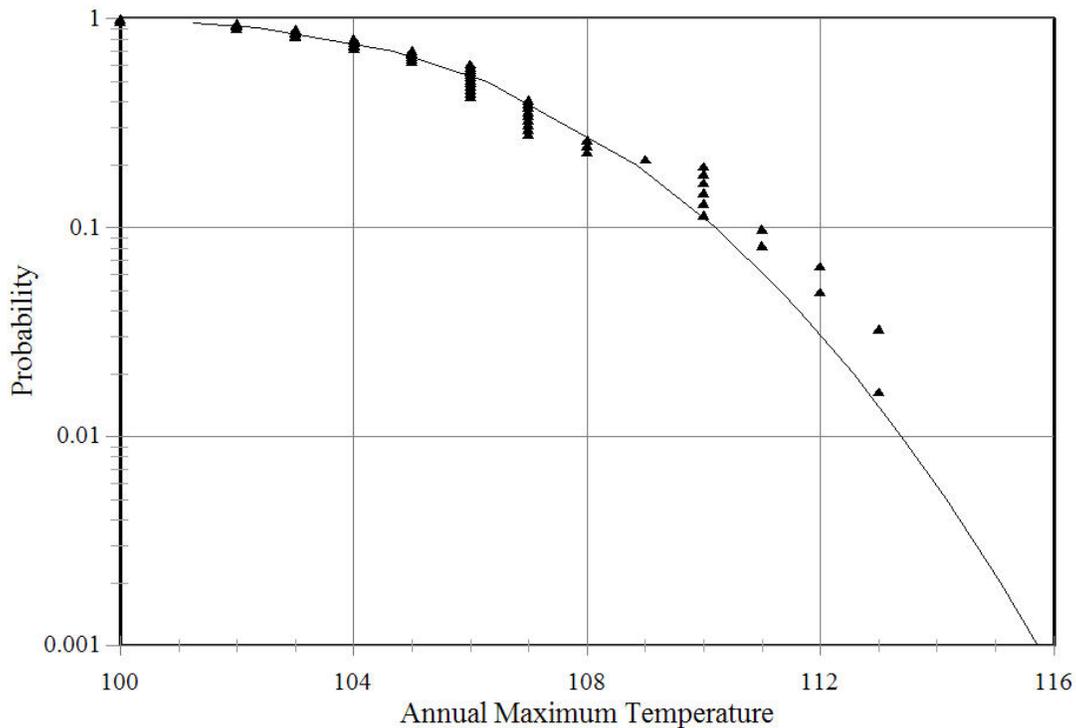
Peak wind gusts for return periods of 2 to 10,000 years are listed in Table 7.5 for heights of 30, 50, 200, and 400 feet above ground. The peak wind gust estimates are based on wind measurements made at the 50-, 200-, 400-foot levels of the tower at the HMS. The peak wind gusts for each return period for these levels were estimated assuming a Type 1 extreme value distribution and maximum likelihood distribution parameters calculated from the HMS data. The peak wind gusts for the 30-foot level were made by first adjusting the peak gusts observed at 50 feet to 30 feet using the technique described by Peterka and Shahid (1998) and then calculating the distribution parameters using maximum likelihood

techniques. Figure 7.7 shows the probabilities of peak wind gusts at all four levels along with the HMS peak wind gust data for 50, 200, and 400 feet.

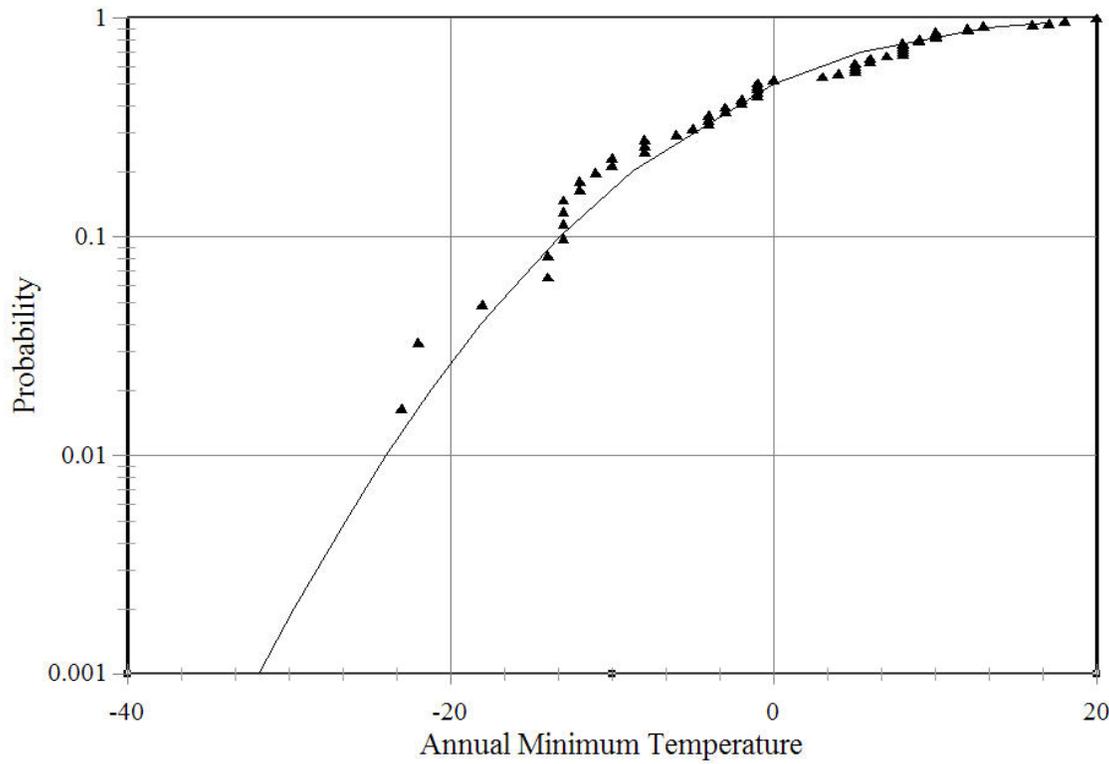
**Table 7.1. Return Periods<sup>(a)</sup> for Annual Maximum and Minimum Temperatures**

Return Period (years)	Maximum Temperature (°F)	Minimum Temperature (°F)
2	106.2	0.0
5	108.8	-8.7
10	110.2	-13.2
20	111.4	-16.9
25	111.7	-18.0
50	112.7	-21.2
100	113.6	-24.0
200	114.4	-26.5
500	115.4	-29.6
1,000	116.1	-31.8

(a) Return periods are the frequency we may expect these temperatures to occur.



**Figure 7.1. Probability (1/yr) of an Annual Maximum Temperature (°F) Exceeding a Given Value**



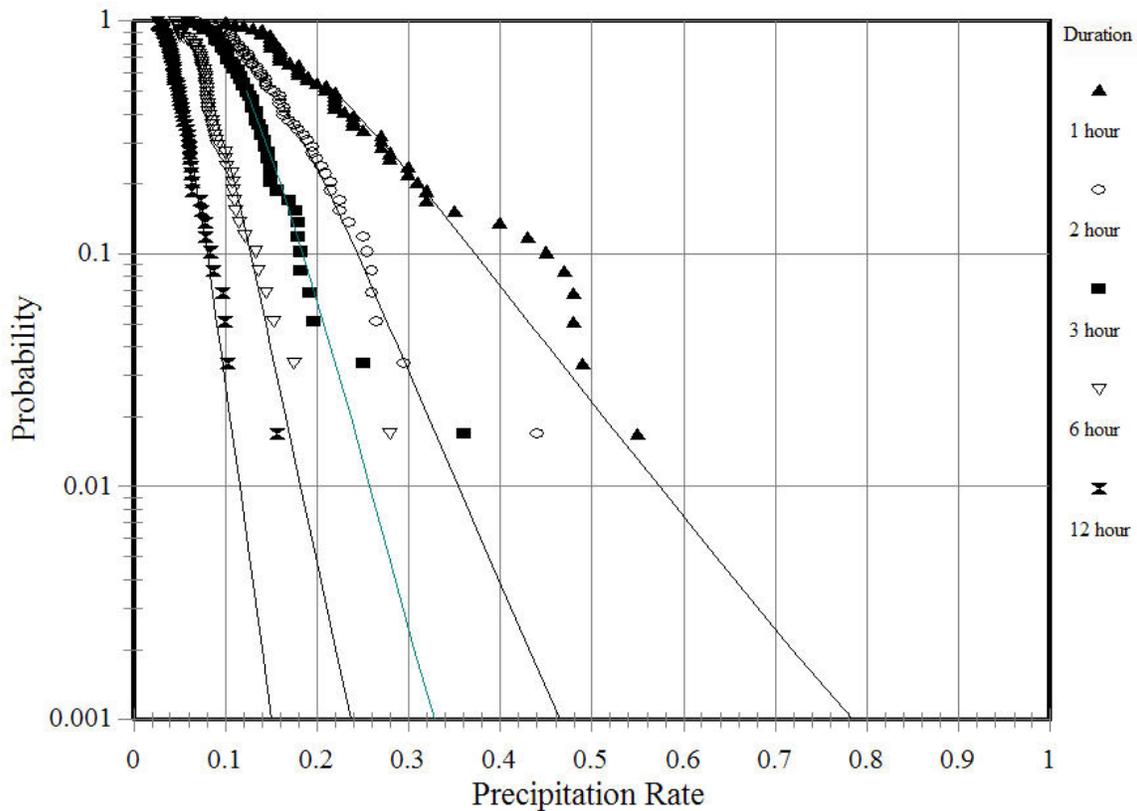
**Figure 7.2. Probability (1/yr) of an Annual Minimum Temperature (°F) Being Less Than a Given Value**

**Table 7.2. Precipitation Rates (inches per hour) for 1 to 24 Hours Duration and Return Periods from 2 to 1,000 Years**

Return Period (years)	Duration					
	1 hour	2 hours	3 hours	6 hours	12 hours	24 hours
2	0.22	0.15	0.12	0.08	0.05	0.03
5	0.31	0.21	0.16	0.11	0.07	0.04
10	0.37	0.24	0.19	0.13	0.08	0.05
20	0.43	0.28	0.21	0.14	0.09	0.05
25	0.45	0.29	0.22	0.15	0.09	0.05
50	0.51	0.32	0.24	0.17	0.11	0.06
100	0.57	0.35	0.26	0.18	0.12	0.07
200	0.63	0.39	0.28	0.20	0.13	0.07
500	0.72	0.43	0.31	0.22	0.14	0.08
1,000	0.78	0.47	0.33	0.24	0.15	0.09

**Table 7.3. Precipitation Amounts (inches) for 1 to 24 Hours in Periods and Return Periods from 2 to 1,000 Years**

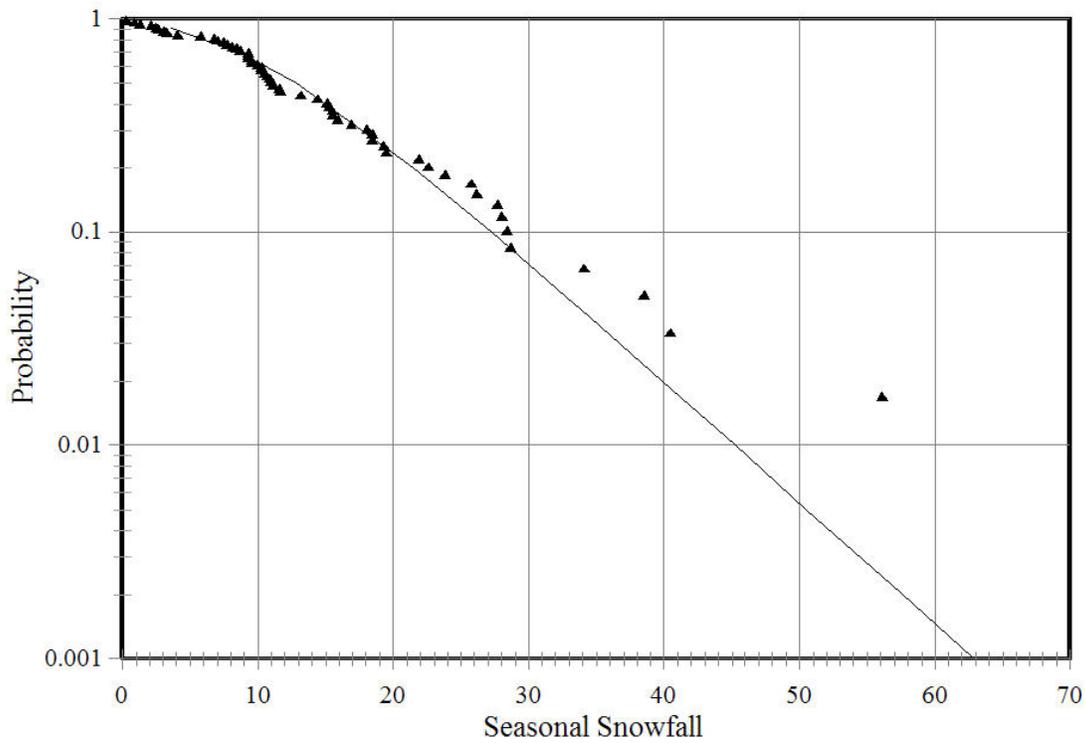
Return Period (years)	Duration					
	1 hour	2 hours	3 hours	6 hours	12 hours	24 hours
2	0.22	0.31	0.37	0.50	0.61	0.71
5	0.31	0.42	0.48	0.66	0.82	0.95
10	0.37	0.49	0.56	0.77	0.96	1.12
20	0.43	0.56	0.62	0.87	1.09	1.27
25	0.45	0.58	0.65	0.90	1.13	1.32
50	0.51	0.64	0.71	1.00	1.26	1.47
100	0.57	0.71	0.77	1.09	1.39	1.62
200	0.63	0.77	0.84	1.19	1.52	1.77
500	0.72	0.86	0.92	1.32	1.68	1.97
1,000	0.78	0.93	0.98	1.42	1.82	2.12



**Figure 7.3. Probability (1/yr) of Precipitation Rate (inches per hour) Exceeding Given Values by Duration**

**Table 7.4. Snowfall Extremes for Return Periods from 2 to 1,000 Years**

Return Period (years)	Seasonal Total (inches)	Single Storm (inches)	Maximum on Ground (inches)
2	12.9	3.7	4.9
5	21.5	6.0	8.1
10	27.3	7.5	10.3
20	32.8	8.9	12.3
25	34.5	9.4	13.0
50	39.9	10.8	15.0
100	45.2	12.2	17.0
200	50.6	13.6	18.9
500	57.6	15.4	21.5
1,000	62.9	16.8	23.5



**Figure 7.4. Probability (1/yr) of Exceeding a Given Seasonal Snowfall (inches)**

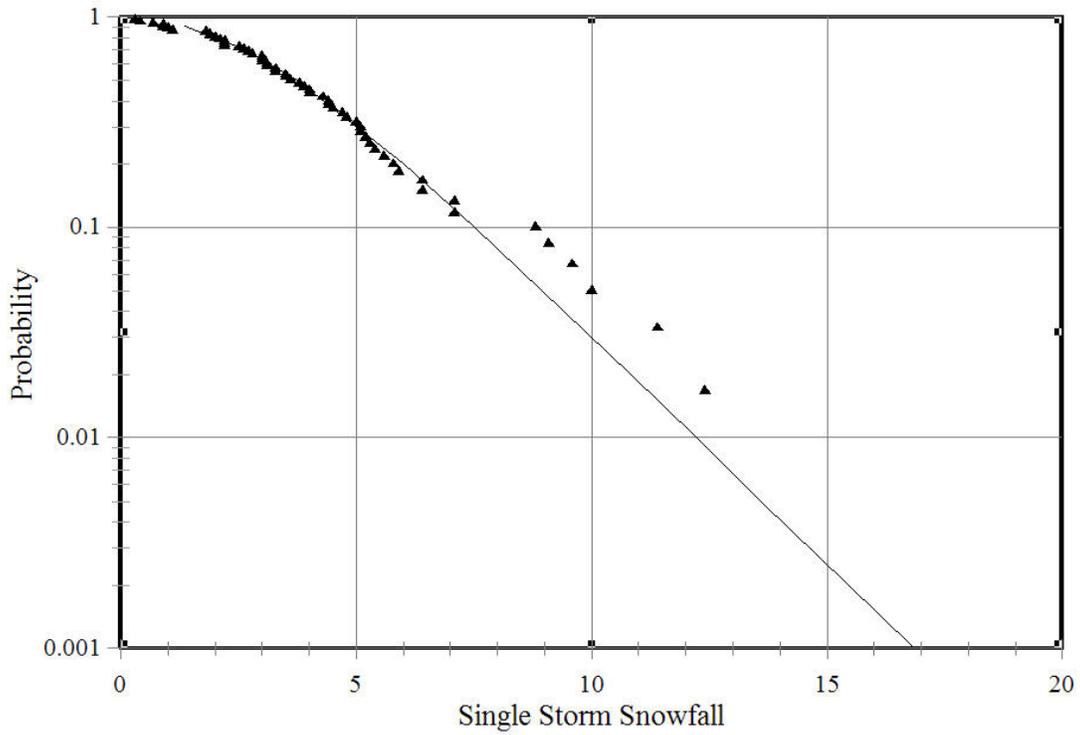


Figure 7.5. Probability (1/yr) of Exceeding a Given Snowfall (inches) in a Single Storm

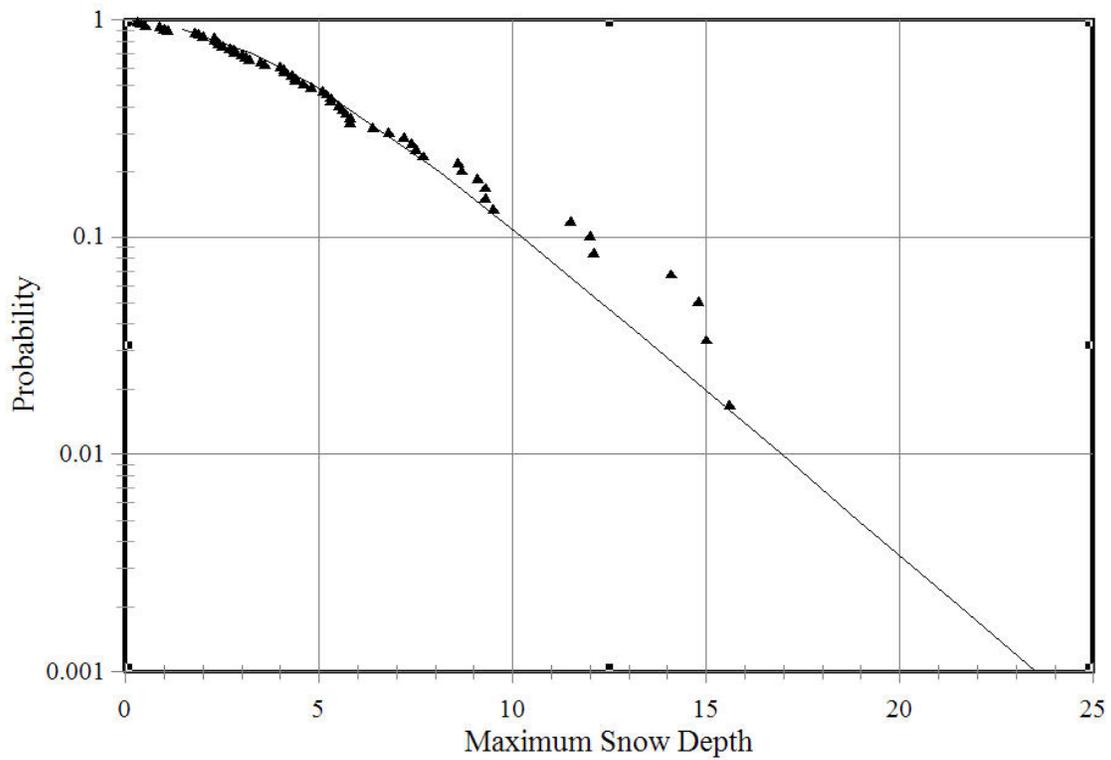
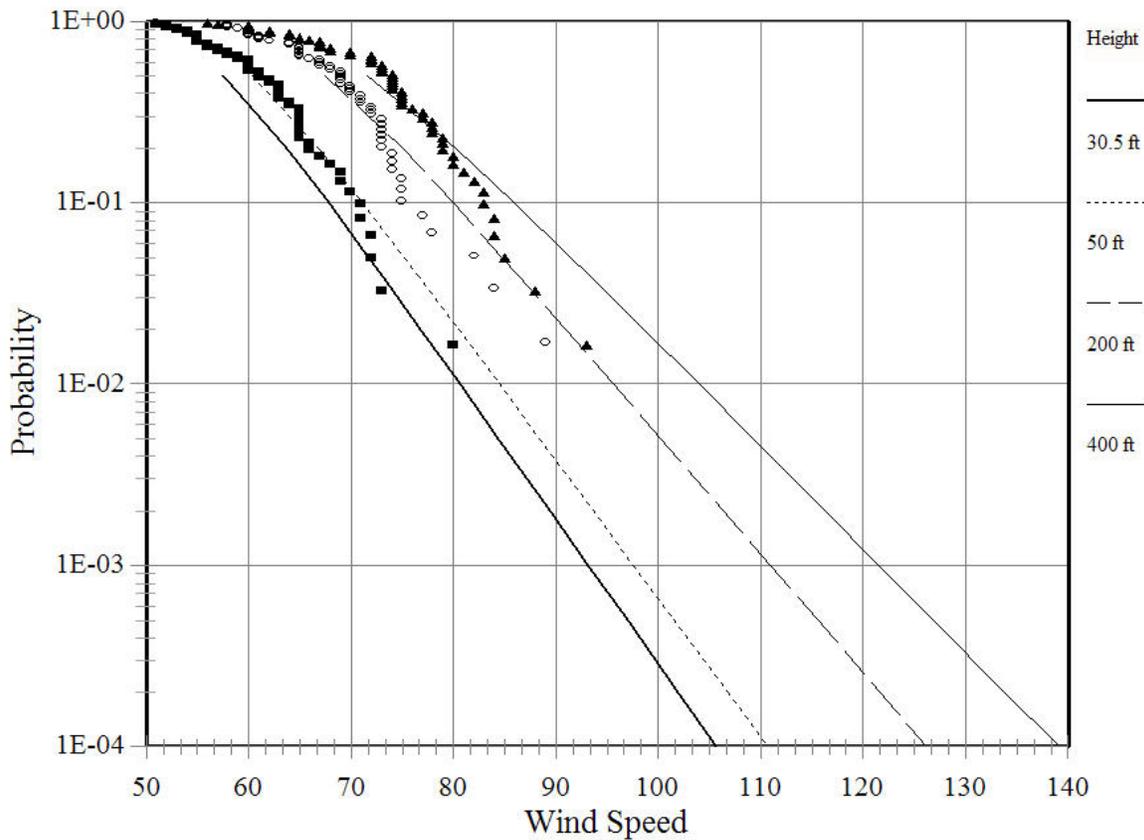


Figure 7.6. Probability (1/yr) of Exceeding a Given Snow Depth (inches)

**Table 7.5. Peak Wind Gusts (mph) for Return Periods from 2 to 10,000 Years**

Return Period (years)	Height Above Ground			
	30 feet	50 feet	200 feet	400 feet
2	57.6	60.3	67.5	71.6
5	63.7	66.8	75.0	80.3
10	67.8	71.1	80.0	86.0
20	71.7	75.2	84.8	91.5
25	73.0	76.6	86.4	93.2
50	76.8	80.5	91.0	98.6
100	80.6	84.5	95.6	103.9
200	84.4	88.4	100.2	109.2
500	89.4	93.7	106.3	116.2
1,000	93.2	97.6	110.9	121.5
2,000	96.9	101.6	115.5	126.8
5,000	101.9	106.8	121.6	133.8
10,000	105.7	110.7	126.2	139.1



**Figure 7.7. Probabilities (1/yr) of Peak Wind Gusts (miles per hour) Exceeding Given Values**